Collaboration on fast luminosity measurements and Machine Detector Interface questions for super B meson factories

Cécile Rimbault (LAL)

Joint TYL/FJPPL-FKPPL Workshop
Bordeaux, 26-28 may 2014

A_RD_08 members

- Japan
  - Sadaharu Uehara
  - Yoshihiro Funakoshi
  - Masako Iwasaki

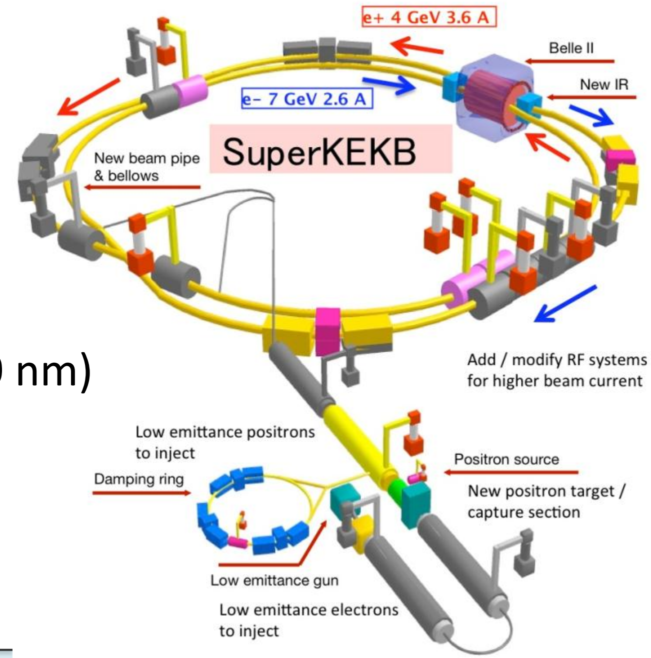
Zero Degree Luminosity Monitor, SuperKEKB

- France
  - Philip Bambade
  - Cécile Rimbault
  - Dima El Khechen (Ph D)
  - Didier Jehanno

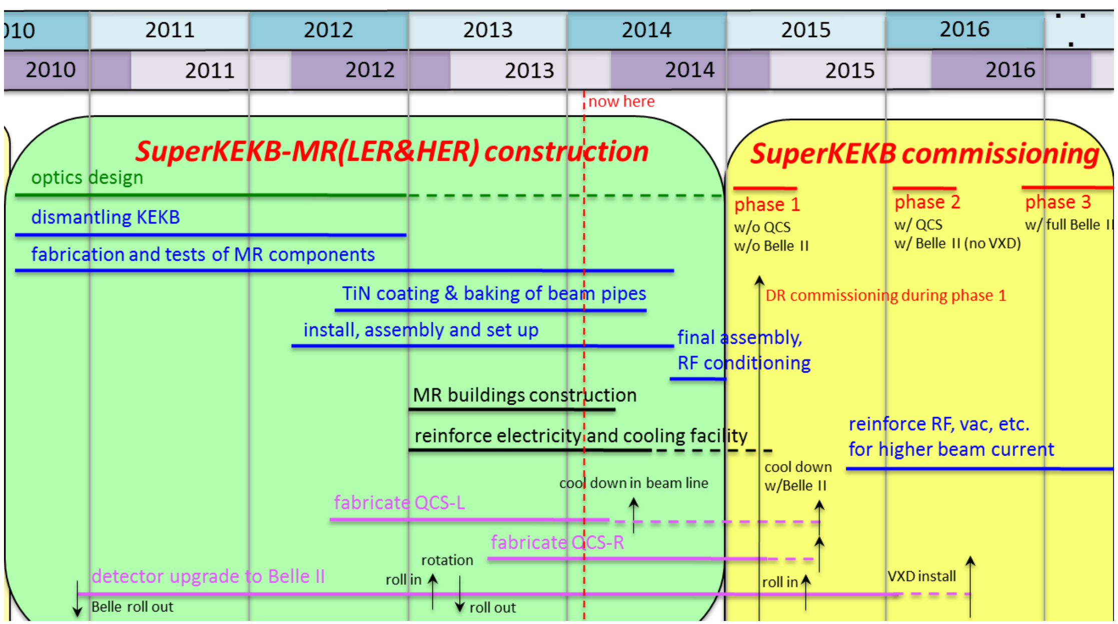
Fast Luminosity Monitoring

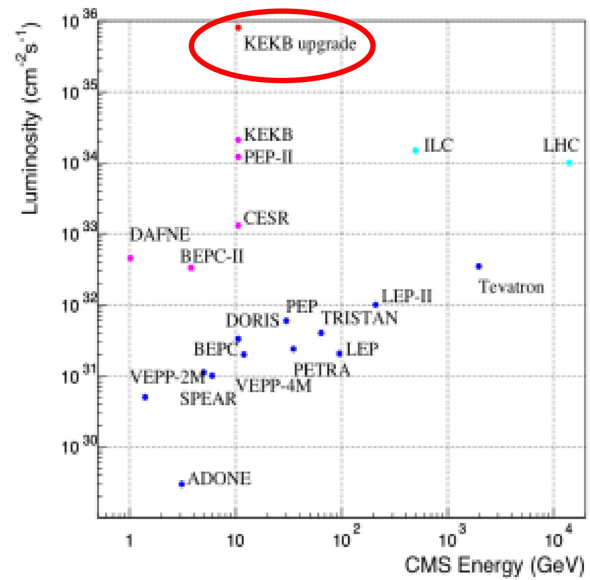
SuperKEKB

- Belle-II @ SuperKEKB: Very high luminosity e^+e^- collider (8 10^{35} $cm^{-2}s^{-1}$) (E_+=4 GeV, E_-=7 GeV)
  - nano-beam scheme, very low beam sizes (60 nm)
  - high currents (coll @ 0.250 GHz)



- Commissioning should start in 2015





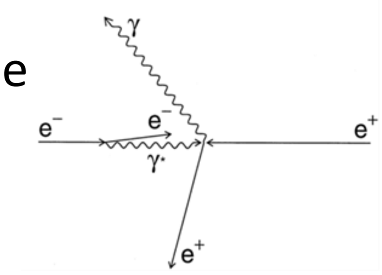
Fast Luminosity Monitoring

- Fast luminosity monitoring is required in presence of dynamical imperfections, for feedback, fine tuning and survey during physics run

- Required precision: $\delta\mathcal{L}/\mathcal{L}$ ~ 10^{-2} to 10^{-3} in 10ms

- Lumi monitoring for each bunch crossing: 2500 bunches, collisions every 4 ns

- Measurement : radiative Bhabha scattering at zero photon angle
  - Large cross-section: ~0.2 barn
  - Proportional to $\mathcal{L}$

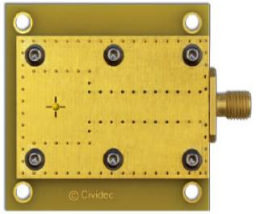


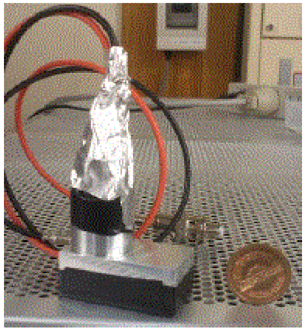
- Technologies: sensors set immediately outside beam pipe

-5x5 mm^2 diamond sensors

(Radiation hardness, Fast charge collection)

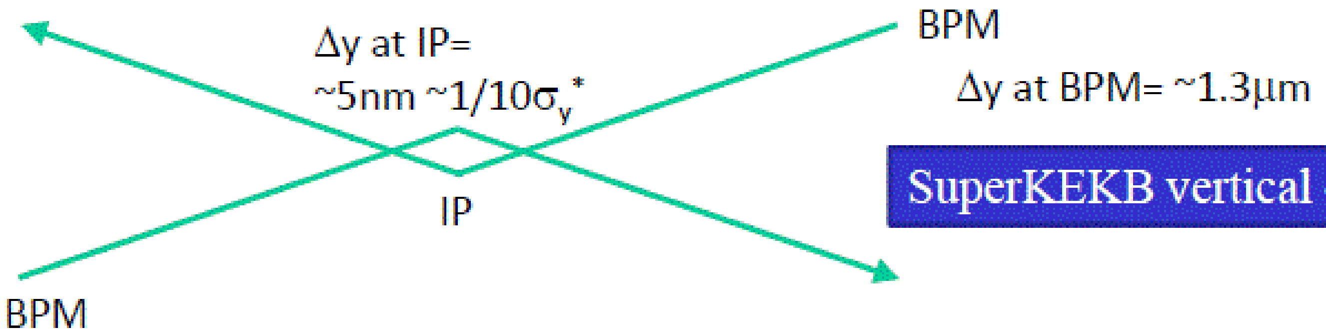
- Scintillator + Cerenkov detector





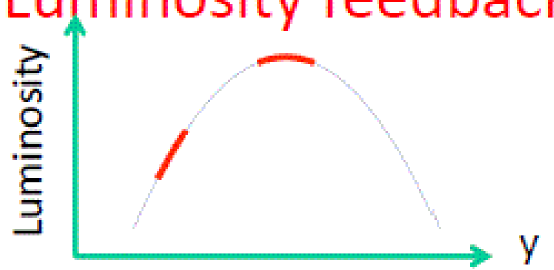
Orbit feedback at IP :Algorithm

- Beam-beam deflection (SLC, KEKB vertical)



SuperKEKB vertical offset

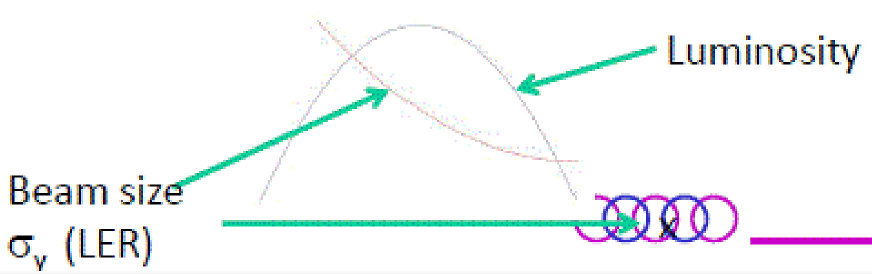
- Luminosity feedback (dithering)(PEP-II)



When we shake the beam at around the peak of the luminosity, there appears twice of the frequency of the dithering frequency.

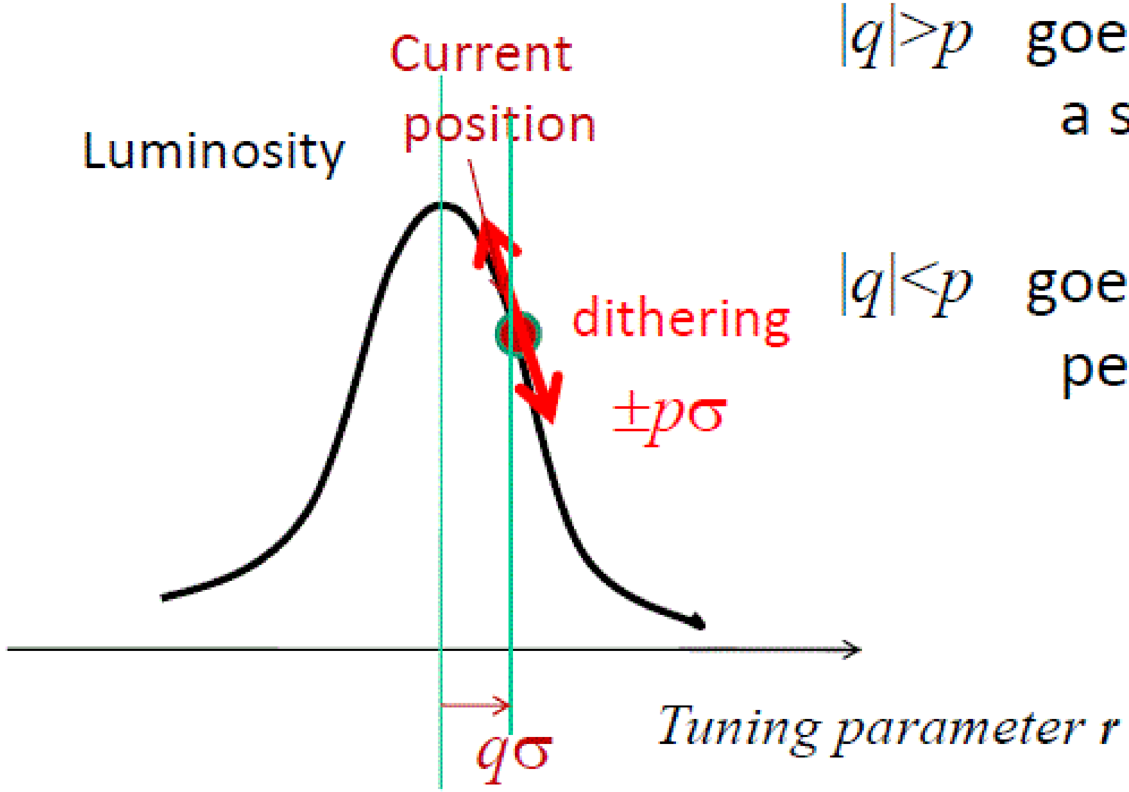
Collaboration with SLAC experts is under way **for SuperKEKB**

- Beam size feedback (KEKB horizontal)



At KEKB before installation of crab cavities, the vertical beam of LER was used for the horizontal orbit feedback at IP.

Illustrating the dithering quantities



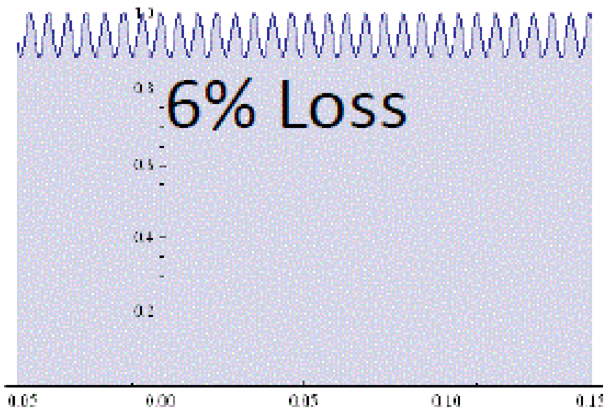
$|q|>p$ goes up and down on a side of slope

$|q|<p$ goes over across the peak

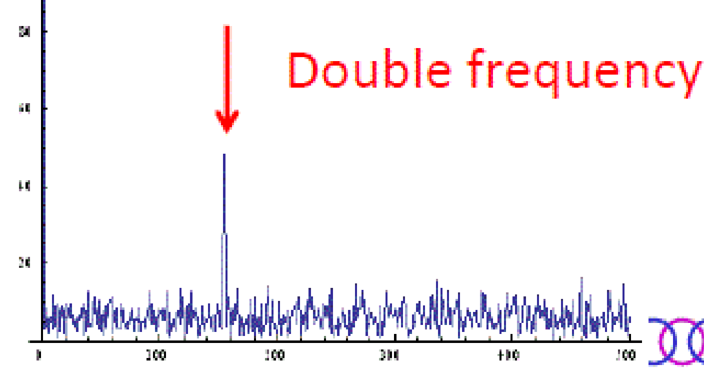
Artificial vibration of luminosity

Simulations for p =0.5, q=0, 50kHz

Luminosity



Power Spectrum



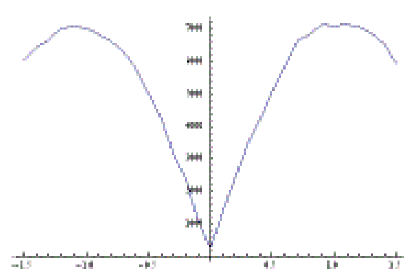
Lock-in Amplifier

$C = S \cos 2pf_0t_i$ $\quad$ t_i: time of each event

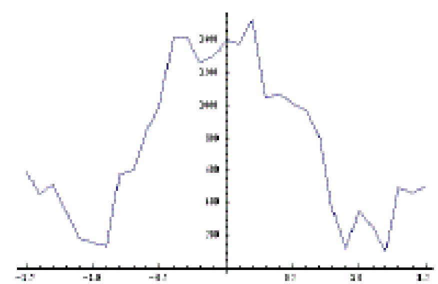
$S = S \sin 2pf_0t_i$ $\quad$ S: summation for one measurement

f_0 : Same as the dithering frequency and twice the frequency

Base freq.



Double freq.



On-going design work for Fast Lumi

- Search for optimal locations for the sensors

  regarding the rate of Bhabha events exiting the beam pipe

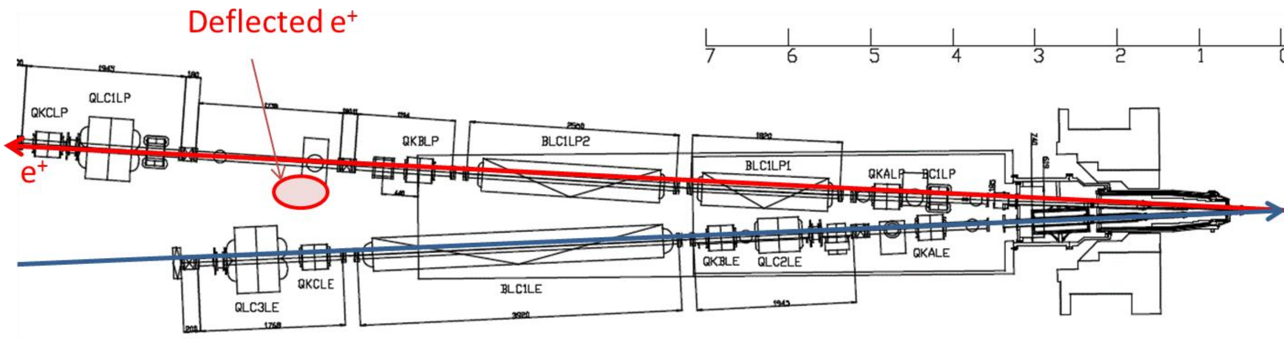
- Beam pipe and sensor geometries

  interaction with the beam pipe material

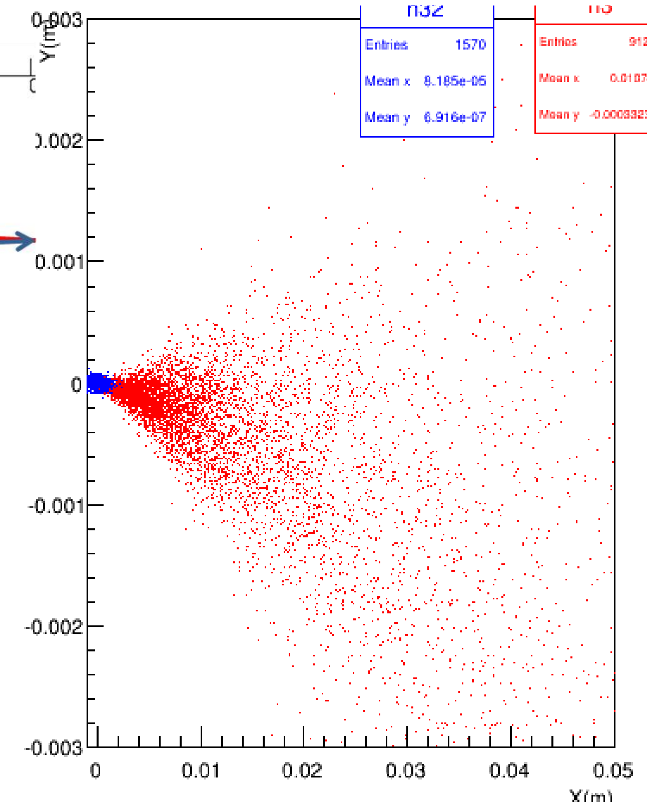
  signal rates in the sensors

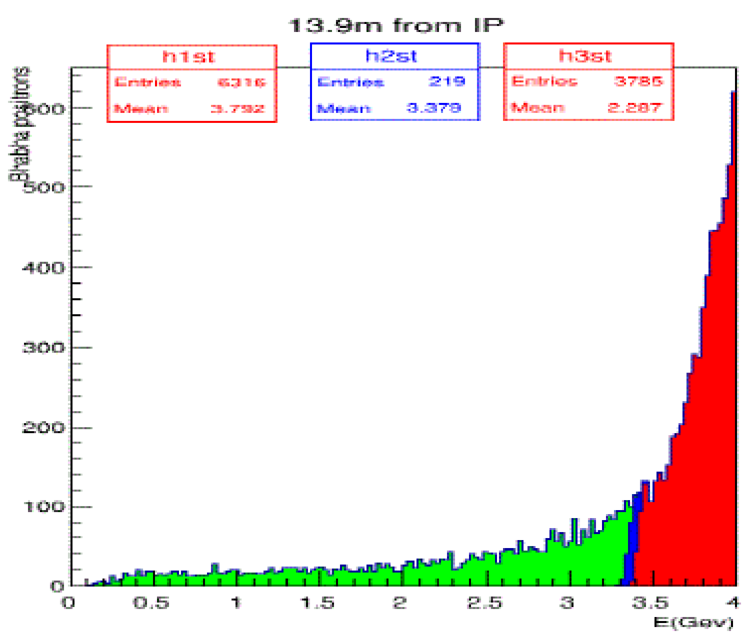
- Sensors signal studies
- Electronic readout

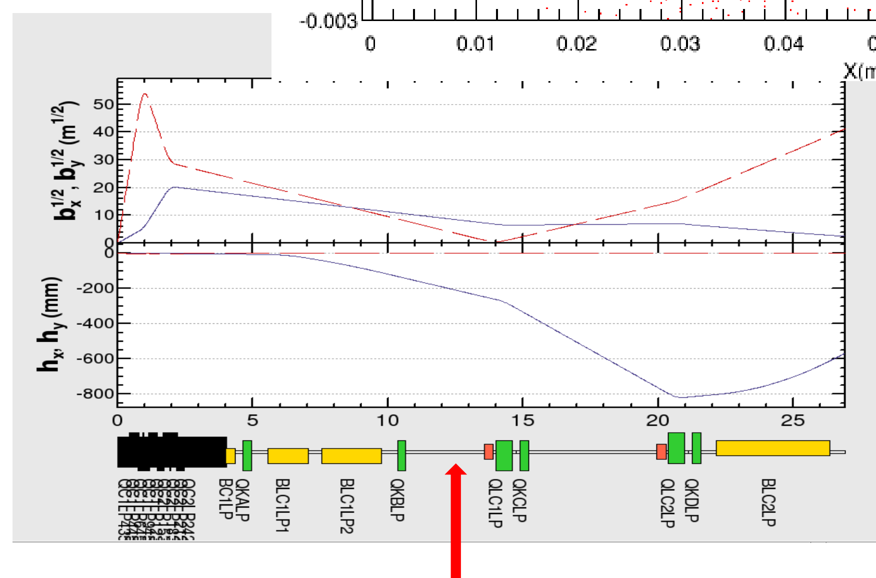
Sensor locations in LER



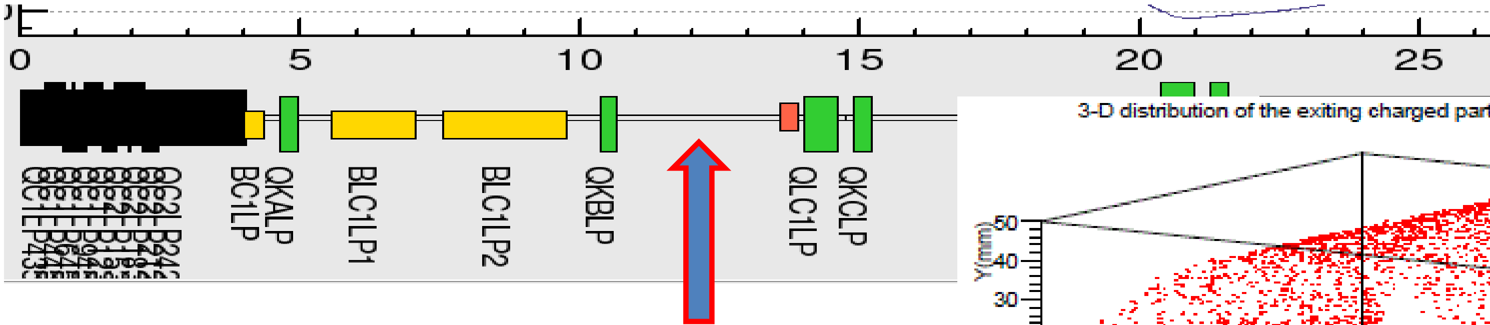
- Low energy e^+/e^- deflected downstream of the IP after bending magnets
- Study of the rate of Bhabhas exiting the beampipe (BP) with SAD tracking code (precision and space)

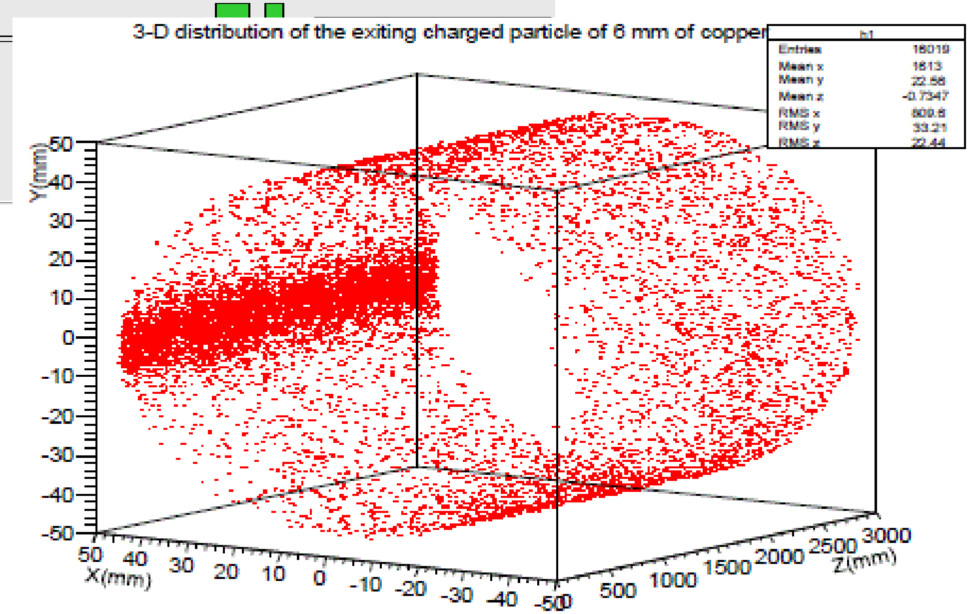




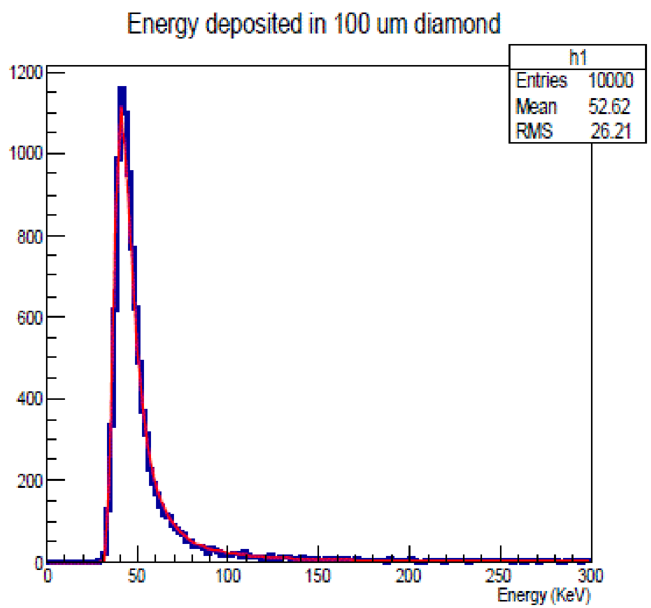


Sensor locations in LER





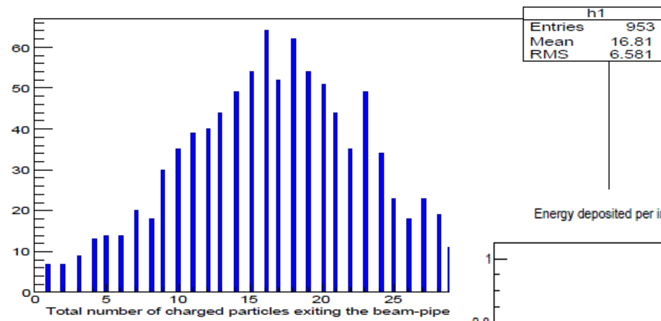
Selected location: after QKBLP, 3m Cu Beampipe, 6 mm thickness, 40 mm radius where
4.7% of the Bhabhas exit the BP and generate secondaries

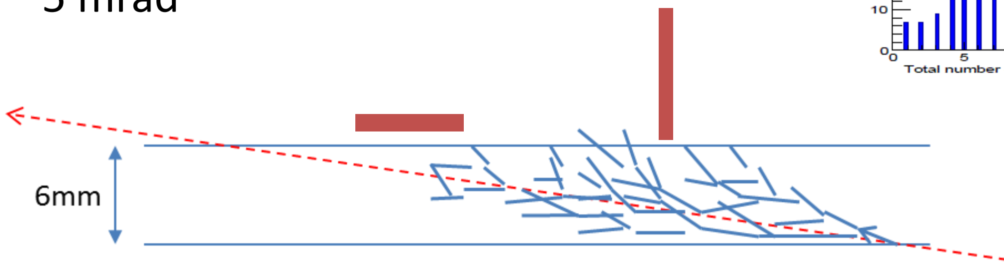


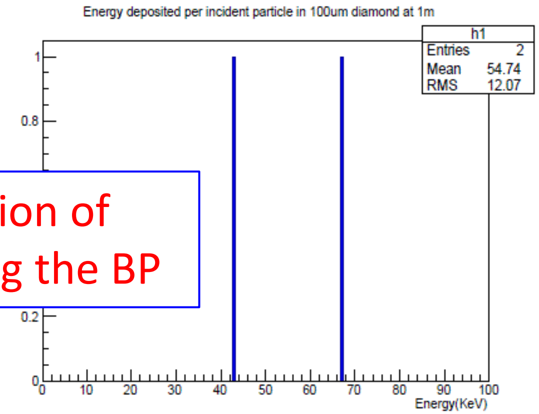
Minimal energy deposition in 100 um thickness diamond sensor to be detected : 1.5 MIP = 78 KeV

Geometry of beam pipe

- At 13.9 m dowstream the of IP, 3.35 GeV Bhabha positrons cross the BP material at 5 mrad

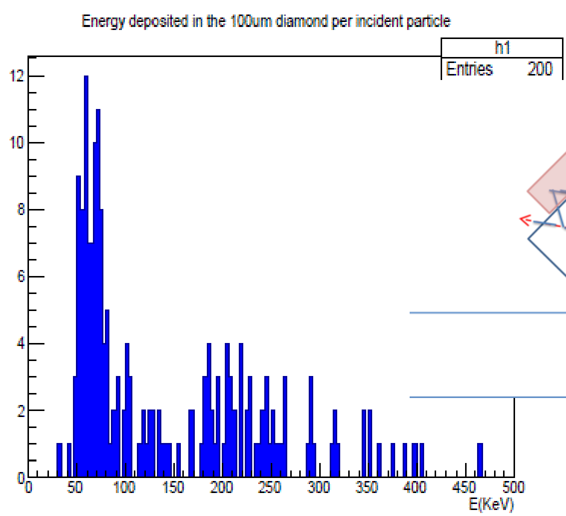


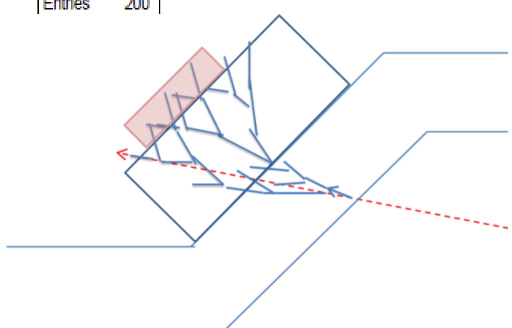


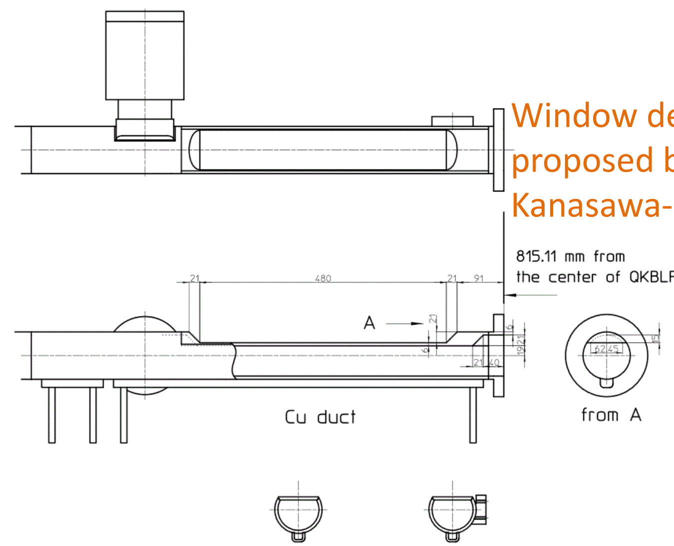


< 0.2% of fraction of Bhabhas exiting the BP

- A modification of the vacuum chamber may be required (window)







Window design proposed by Kanasawa-san

Geometry of beam pipe : summary on precisions

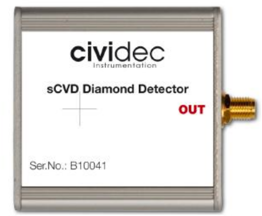
	Luminosity ($cm^{-2}.s^{-1}$)	Required Precision in 10 ms (Nb of particles)	Number of particles collected in 10 ms
No Window	10^{34}	10^{-2} (>10^4 part.)	**1.4 10^3**
No window	8 10^{35}	10^{-3} (>10^6part.)	**1.2 10^5**
Window	10^{34}	10^{-2} (>10^4part.)	**4.4 10^4**
Window	8 10^{35}	10^{-3} (>10^6part.)	**3.5 10^6**
Window+radiator	10^{34}	10^{-2} (>10^4part.)	**1.5 10^5**
Window+radiator	8 10^{35}	10^{-3} (>10^6part.)	**1.2 10^7**

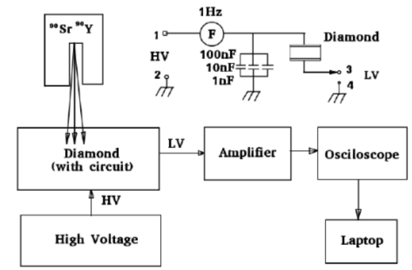
A window is required to reach the precisions we aim

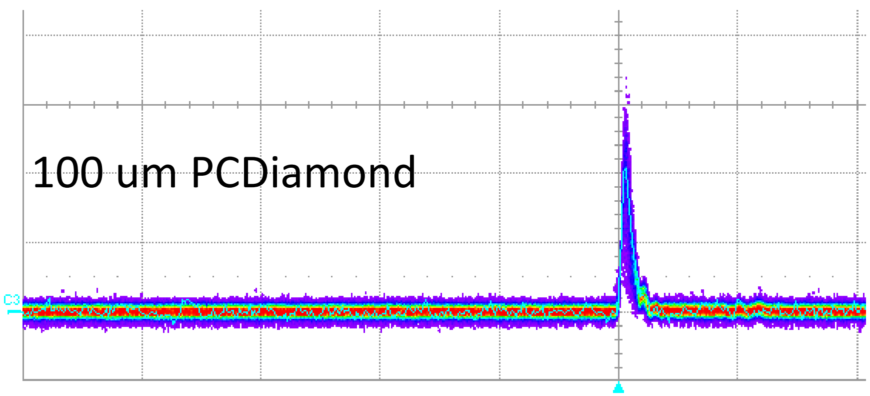
Diamond sensors

Diamond sensor technology is already studied at LAL since 2012 for ATF2 (prototype of ILC final focus)

For SuperKEKB: signal width < 1-2 ns, since 4 ns bunch spacing



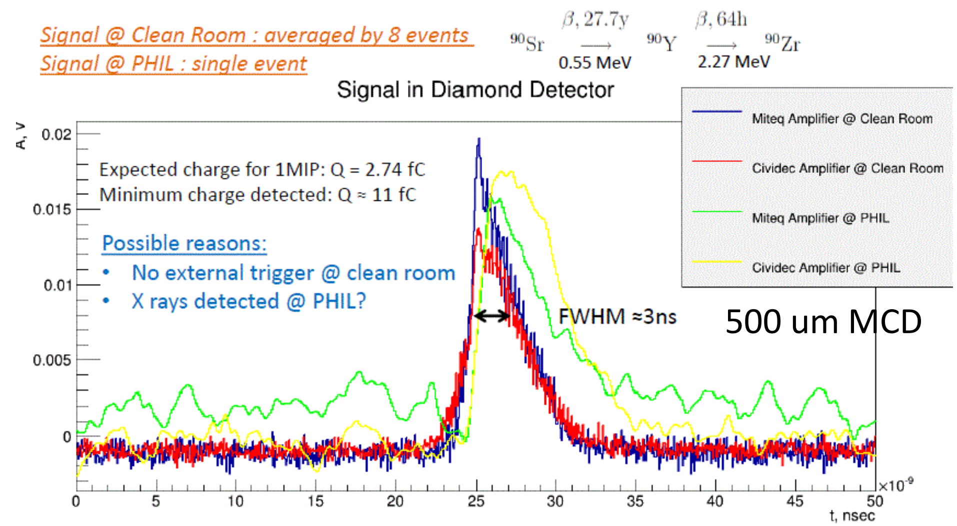




Measure	P1:sdev(C3)	P2:rise(F3)	P3:width(F3)	P4:fall(F3)	P5:max(C3)
value	3.3 mV	451 ps	922 ps	1.562 ns	104 mV
mean	3.163 mV	450.55 ps	921.65 ps	1.56241 ns	95.87 mV
min	2.4 mV	451 ps	922 ps	1.562 ns	28 mV
max	4.0 mV	451 ps	922 ps	1.562 ns	169 mV
sdev	213 µV	---	---	---	25.24 mV
num	518	1	1	1	518
status	✔				✔

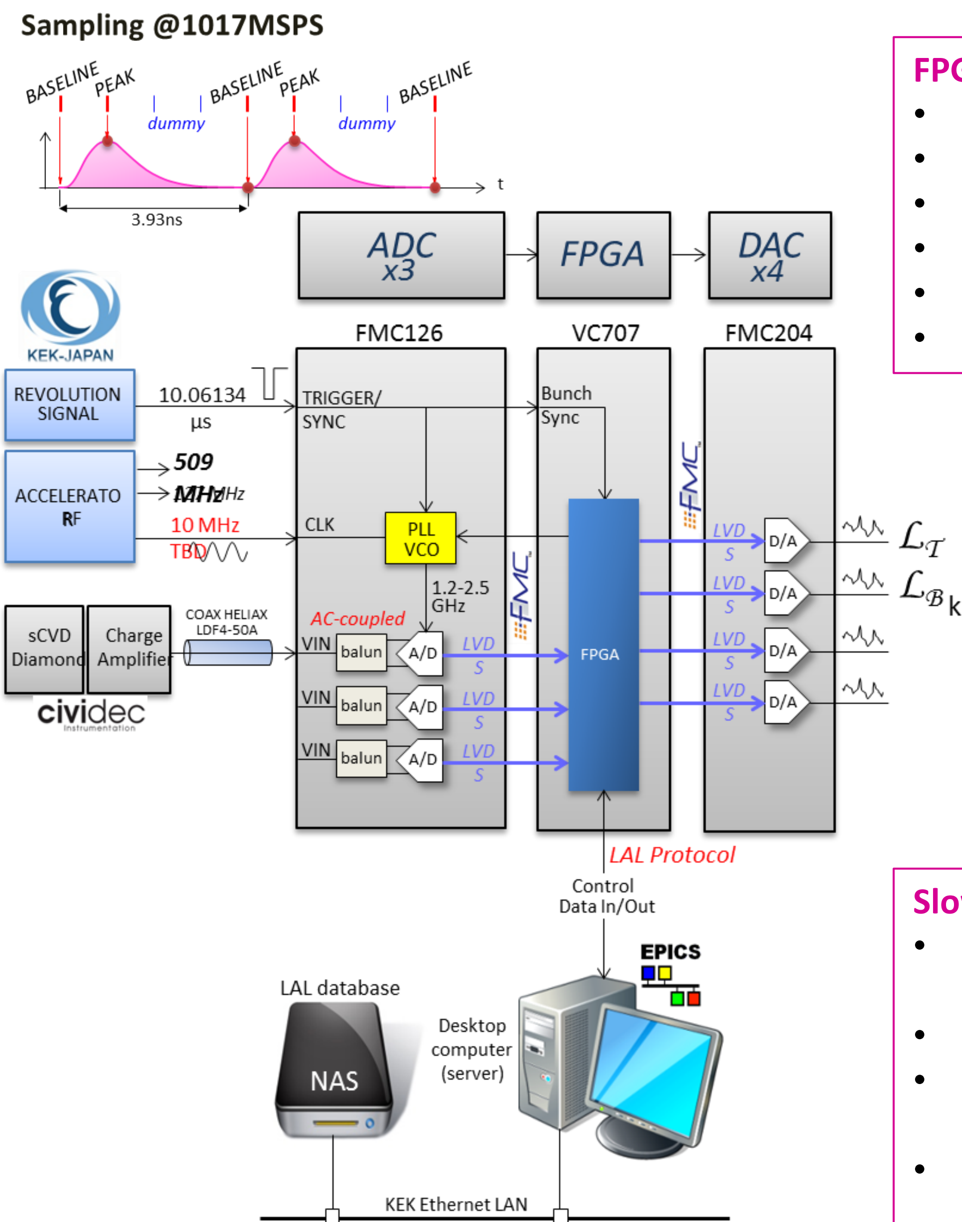
Courtesy of E. Griesmayer, CIVIDEC

Minimum Signal Detection



S. Liu (ATF2 group)

READOUT



FPGA-based digital acquisition

- Synchronized to acc. RF Clock @ 10MHz
- Sampling every 1ns
- Phase adjustment by the ADC board
- Peak value acquisition : determines Bhabha events nb
- 2015 : signal FWHM 10ns (140µm diamond thickness)
- 2016 : signal FWHM ~2ns (100µm diamond thickness)

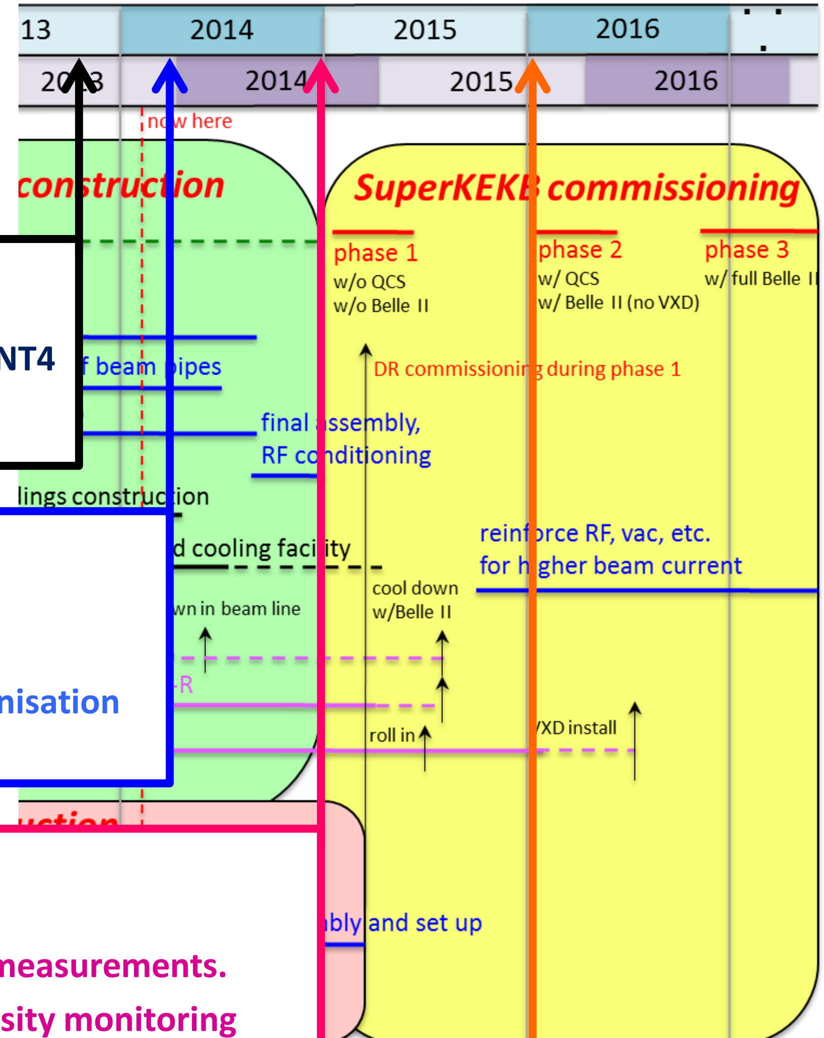
Outputs

- Train Integrated Luminosity over 1ms
- Bunch Integrated Lumi over 1ms : 2500 values @254 MHz

Slow Control / Interface

- Sampling controlled by local Linux machine (LM) connected to FPGA board
- TIL and BIL directly computed by FPGA and read by LM
- EPICS protocol installed on LM and provides TIL + BIL to EPICS users in real time (1ms)
- DAQ also comes with 4 Analog outputs
  - Controlled by EPICS users
  - Used for tests, debug and orbit feedback

Schedule



✓ **Fall 2013-Spring 2014:**

- Study of Bhabha signals and background estimations
- Study of secondaries interaction with beam pipe using GEANT4
- Investigation of optimal sensor location and geometry

✓ **Spring 2014-Automn 2014 :**

- Prepare fast < 4ns sensor and 250 MHz readout
- Laboratory tests (clean room and Phil @LAL…)
- Prepare initial setup and data acquisition for beam synchronisation and background tests at SuperKEKB

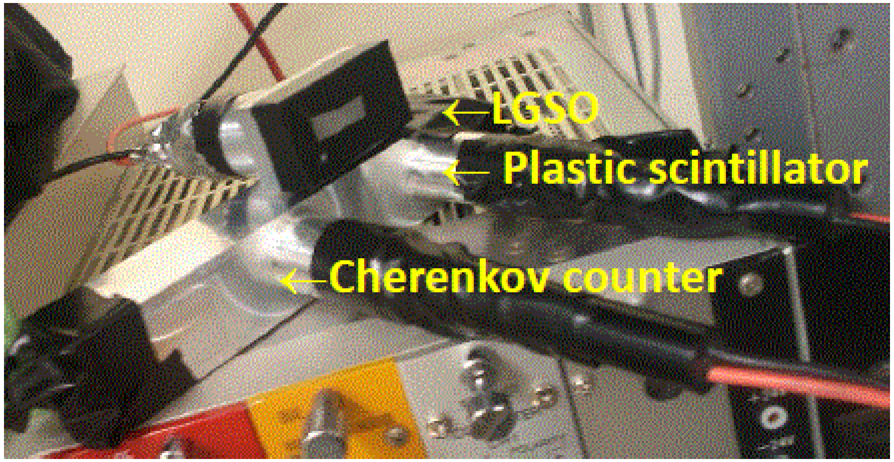
✓ **2015:**

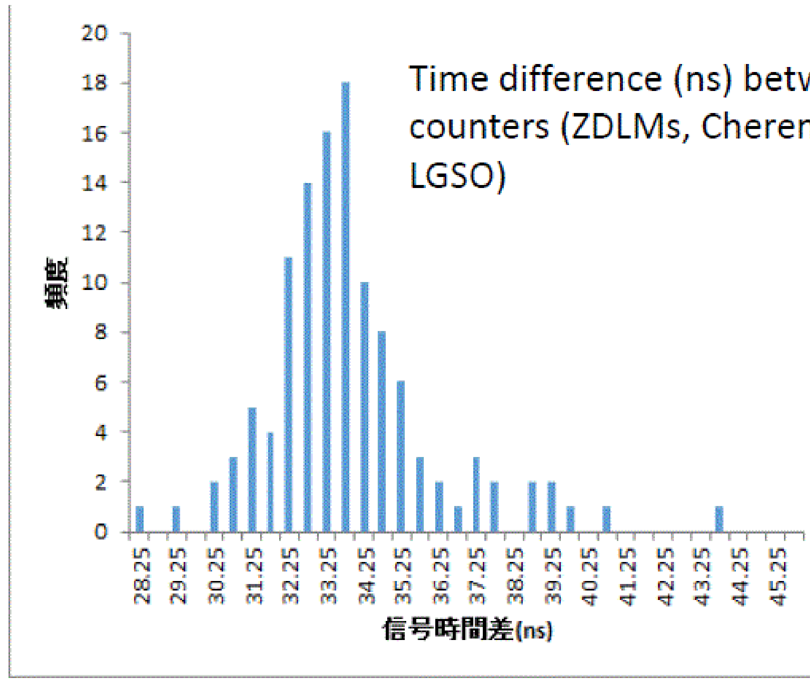
- Installation and tests at SuperKEKB
- Synchronisation test and initial background measurements.
- Finalise design of data acquisition for luminosity monitoring

✓ **2016:**

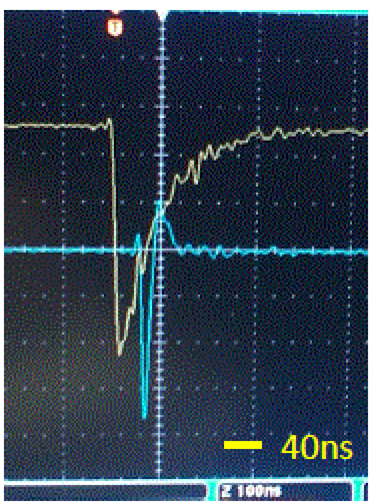
- First data for luminosity monitoring
- Analysis (Dima's PhD)
- Optimisation in context of luminosity feedback

Cosmic-ray test for ZDLM counters





Time difference (ns) between two counters (ZDLMs, Cherenkov and LGSO)



←LGSO

← Plastic scintillator

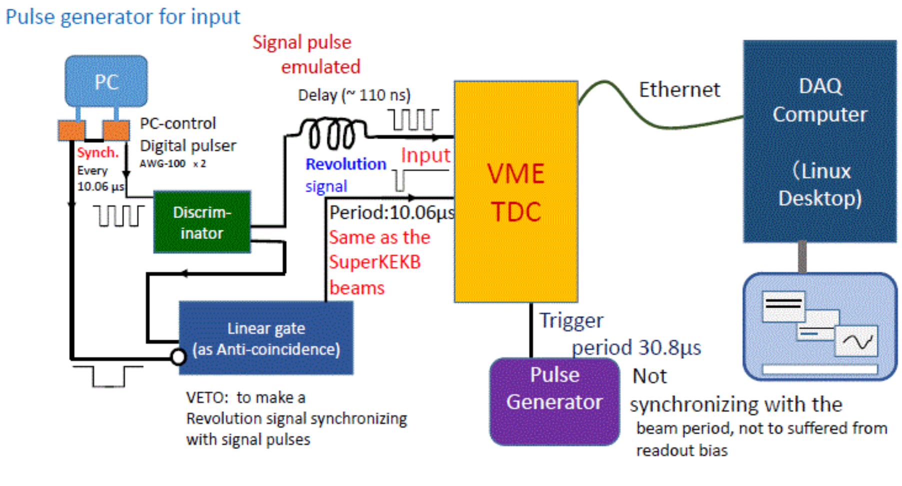
Large light yield (peak >500 mV for cosmic ray)

A-little slow decay time (~50ns,

Counting high freq. limited < ~ 20 MHz)

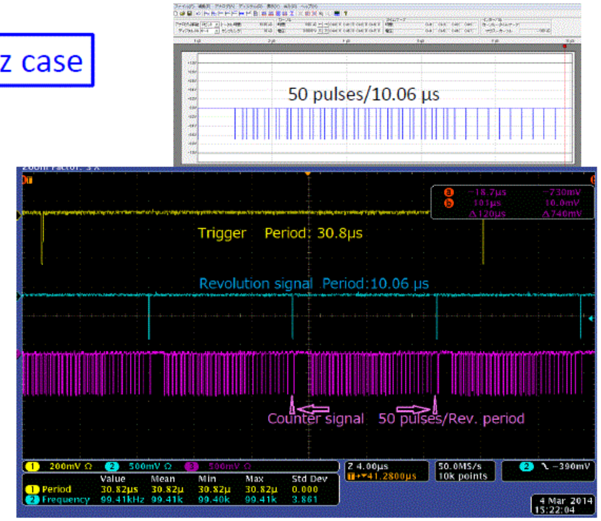
Data acquisition test for TDC module for ZDLM

DAQ system for TDC measurement for bunch-by-bunch luminosity



Input pulse pattern (emulated signal)

5MHz case



1 pulse data ≡ 1 word = 4 Bytes

Data Fill -- due to performance of L1 buffer

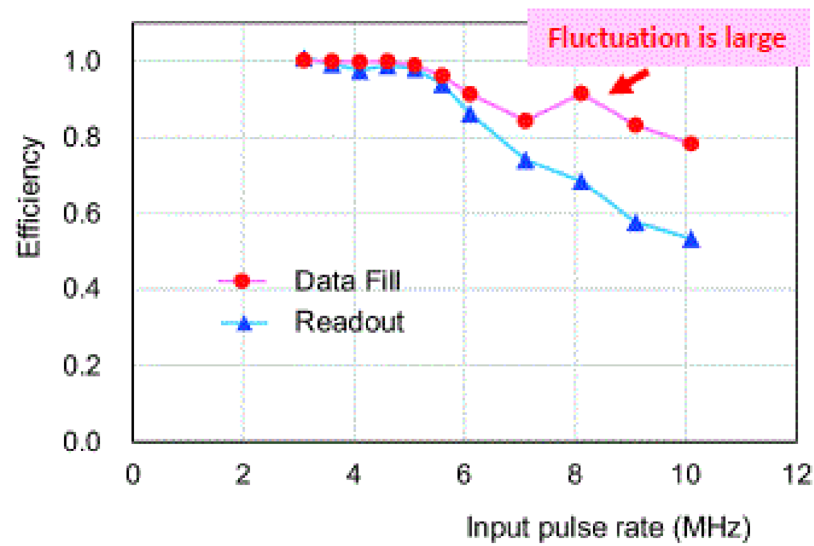
There should be a capacity up to 10MHz.

Unstable efficiency – affected by buffering for readout

Present limit for Readout rate – 21MB/s is smaller than the limit of Ethernet

Depending on performance of PC and program

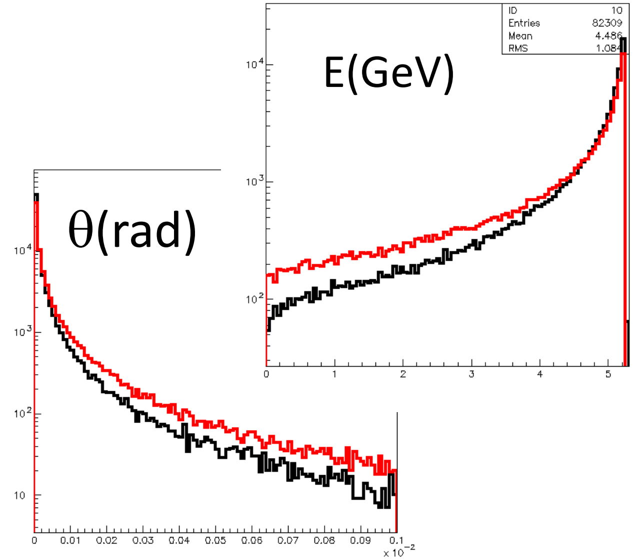
to be still improved



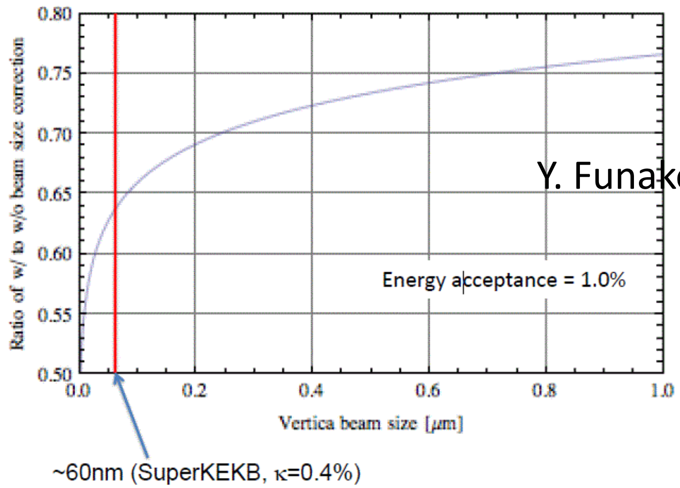
QED and Beam-beam studies

- Radiative Bhabha cross-sections uncertainties: Comparaison of several generators, based on different approaches:

  - **BBBrem**: using equivalent photon approximation (Weizsaecker-Williams)
  - **RABHAT**: calculation in QED and electroweak theory using exact squared matrix element keeping e mass



- Reduction of the cross section due to finite beam-size



Y. Funakoshi (KEK, joint bkgd w.s., Feb. 2012)

Next Plans

For ZDLM:

- Preparation of crystal scintillator and Cerenkov type ZDLM for early stage SuperKEKB Commissioning.
- Measurement of time structure of the signals near the accelerator (photon radiations from electron-residual-gas collisions)

For Fast Lumi:

- Diamond sensors characterization
- Development of an ADC running at 250 MHz
- Development of a fast FGPA for TIL and BIL
- First tests of a complete readout during single beam commissioning (01/2015)
- Design of final sensor for colliding beams from 01/2016
- Generator comparison for predictions of the zero-angle radiative Bhabha cross section including beam size effect

Lot of fruitful exchanges between KEK and LAL (monthly meetings and visits)